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SUS QUALITY ASSESSMENT

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13. ABSTRACT

The detonation pressure time curves recorded aboard the shooting ships, the USNS Silas Bent and the USNS Bartlett, were processed to acquire quality assurance statistics for the SUS used for acoustic sources. Bubble pulse periods were determined for each detonation from which an equivalent detonation depth was derived. For statistical purposes, the detonation depths are grouped in 2 foot classes centered on the even foot for the MK 61 (60 feet) and 10 foot classes centered on the decade, for the MK 82 (300 feet).

The fluctuation in source levels for each 1/3 octave band ot interest; 25, 50, 100, 160 and 250 Hz, was determined for each depth range class discussed above. The corrections range from +1.0 to -1.0 db, and are given in 0.5 increments in Table 3 of Chapter 3. The computations are based on the Gaspin & Shuler and the Weston formulations, since these are the only procedures which can be currently employed to obtain this information.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
CHURCH ANCHOR						
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SUS						

SUS QUALITY ASSESSMENT

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SUMMARY

The detonation pressure time curves recorded aboard the shooting ships, the USNS Silas Bent and the USNS Bartlett, were processed to acquire quality assurance statistics for the SUS used for acoustic sources. Bubble pulse periods were determined for each detonation from which an equivalent detonation depth was derived. For statistical purposes, the detonations depths are grouped in 2 foot classes centered on the even foot for the MK 61 (60 feet) and 10 foot classes centered on the decade, for the MK 82 (300 feet). For the SUS deployed by the Bent, it is recommended that the 54, 56, 58, and 60 foot classes be processed for the MK 61s and the 280, 290, 300 and 310 foot classes be processed for the MK 82s. The data from the Bartlett is both of lower quality and inconsistent with that of the Bent; therefore, no recommendations can be made regarding the data derived from the SUS deployed by the Bartlett. ARL, University of Texas has been furnished listings and a digital tape from which the recommended shots can be determined.

The 1/3 octave band source levels for SUS have been extensively investigated in other programs.

Measured and predicted levels cover a range of as much as 8 db for the 25 Hz band. The spread is lower for other frequencies, but is still of the order of 5 db. Several sets of source levels are given in Tables 1 and 2 of Chapter 2. It is recommended that a single set of source levels be used for all propagation loss determinations so that comparisons can be made. The source levels used should be listed in all propagation loss reports.

The fluctuation in source levels for each 1/3 octave band of interest; 25, 50, 100, 160 and 250 Hz, was determined for each depth range class discussed above. The corrections range from +1.0 to -1.0 db, and are given in 0.5 increments in Table 3 of Chapter 3. The computations are based on the Gaspin & Shuler and the Weston formulations, since these are the only procedures which can be currently employed to obtain this information.

CHAPTER 1
SUS QUALITY ASSESSMENT

Introduction

During the CHURCH ANCHOR Exercise, a series of
SUS bombs were deployed by the vessels USNS Silas
Bent and USNS Bartlett for the purpose of measuring
acoustic propagation loss. Quality assurance proce-
dures were instituted to ensure that the data obtained
would not be affected by variations in source level
or detonation depth. Magnetic tape recordings of
the SUS pressure signals were obtained by each of
the shooting ships. These tapes were processed to
determine the bubble pulse period from each of the
SUS bombs used for the propagation loss studies.
From the bubble pulse period of the source, deviations
in shot depth and band levels can be determined. The
processing technique, results, and recommendations,
are presented.

Basic Data - USNS Silas Bent

The data obtained by the USNS Silas Bent was re-
corded in the FM mode on magnetic tape using two
different sensors; (1) a towed seismic array, and
(2) a hull mounted 3.5 kHz transducer. Time code
IRIG B and voice annotations were also recorded in
the direct mode. Approximately 3,222 SUS bomb

shots were dropped from the Bent, distribution by
type is shown in Table 1. The recorded data is
considered to be of excellent quality, with two
minor exceptions, tape 40 was blank, i.e., one
45 minute sequence was not recorded, and there
was no time code on the last ten 45 minute sequences
due to equipment failure - the result being "slightly
lower confidence level" for that portion of the
data.

Basic Data - USNS Bartlett

The data obtained by the USNS Bartlett was
recorded in the FM mode from a owed hydrophone
using a high, medium, and low gain channel. Time
code IRIG B and voice annotations of time were
also recorded in the direct mode. Approximately
270 SUS's were dropped from the Bartlett, dis-
tribution by type are shown in Table 2. The data
was recorded on 5 magnetic tapes. During the 2nd
tape, the time code carrier shows slowing tape speed
and extensive momentary decelerations and accelerations.
Near the beginning of tape 4 the recorder was replaced
and the data quality was good for tape 5.

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TABLE 1

Tabulation of SUS Statistics for
Those Dropped by the USNS Silas Bent

SUS Type	MK 61	MK 82	MK 61	MK 64
Nominal Detonation Depth	800	300	60	60
Nominal Explosive Yield	1.8 lb	1.8 lb	1.8 lb	1.1 oz
Number Dropped	697	695	696	829
Number Processed	0	655	654	0
Number Not Recorded	–	14	14	–
Number Not Processable	–	0	2	–
Dud	–	26	26	–
Number Processed Outside of Depth Limits:*				
Bubble Pulse High	–	24	34	–
Bubble Pulse Low	–	43	18	–

*Discussed on page 16.

TABLE 2

Tabulation of SUS Statistics for
Those Dropped by the USNS Bartlett

| SUS Type	MK 61	MK 82	MK 61
Nominal Detonation Depth	800	300	60
Nominal Explosive Cut	1.8 lb	1.8 lb	1.8 lb
Number Dropped	90	89	89
Number Processed	0	58	60
Number Not Recorded	–	14	13
Number Not Processable	–	11	10
Dud	–	6	6

Data Processing System

A block diagram of the data processing system is shown in Figure (1). The data from the tape recorder is preprocessed before being digitized for processing. The computer provides five functions:

1. Determination of bubble pulse period

2. Time code reader

3. Time code search

4. Display controller

5. System controller

The operator's chief function is to serve as an on-line quality assurance monitor. To assist him in this role the bomb shot is displayed together with the computer determined bubble pulse period on an oscilloscope for immediate observation; at the operator's option, a hard copy can be made for further study. System status and bubble pulse periods are presented on the TTY printer.

The data channel from the recorder is amplified to convert a nominal 1 volt rms signal from the recorder to a 10 volt peak signal for input to the 13 bit analog to digital converter. The data channel is sampled at a nominal 8 kHz derived from the time code carrier.

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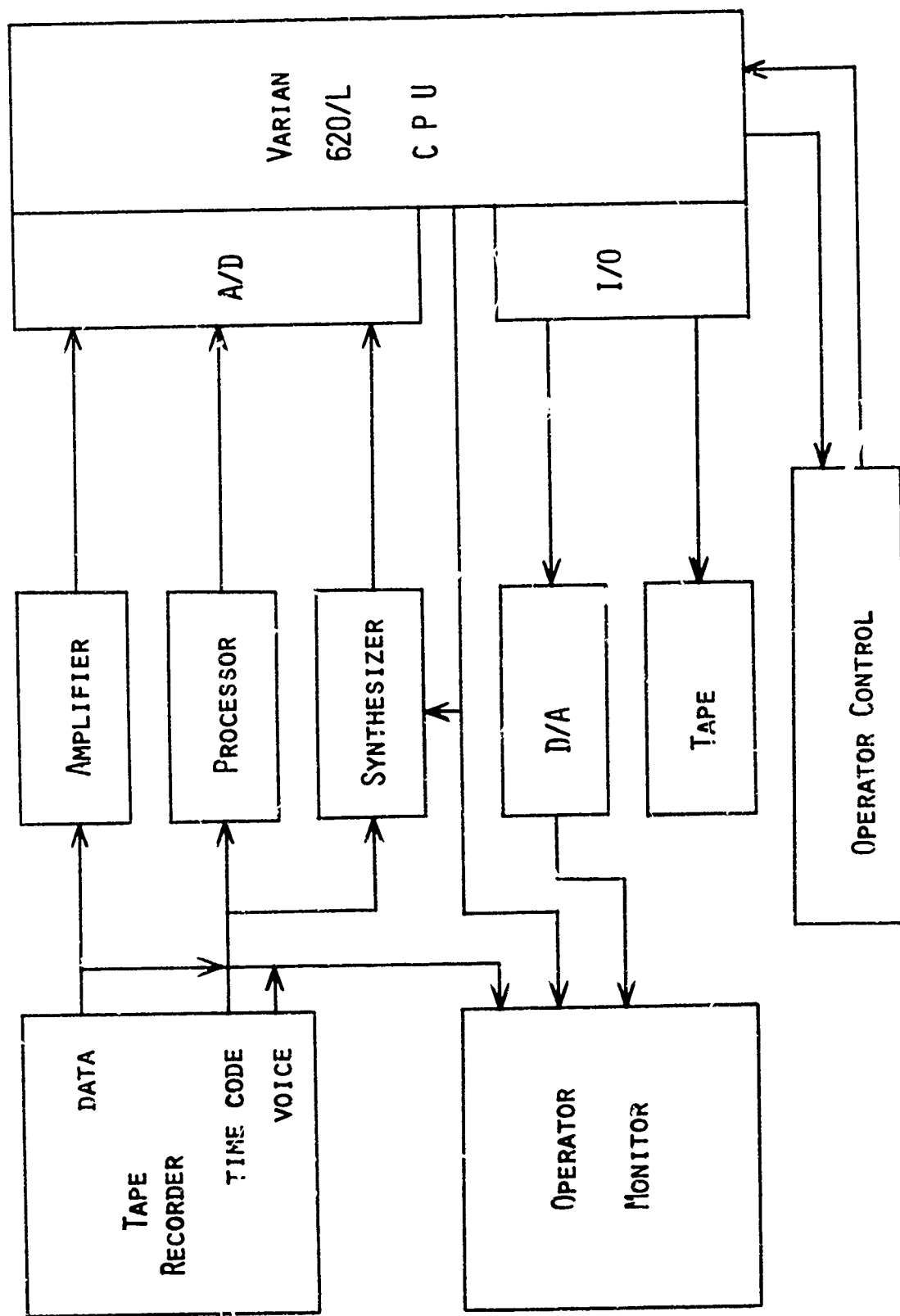
FIGURE (1). BLOCK DIAGRAM OF BUBBLE PULSE PROCESSING SYSTEM.

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The time code channel from the recorder is
utilized in two ways: (1) to determine the time;
and, (2) to furnish a reference frequency to remove
tape recorder speed errors. For determining time,
the modulated time code is processed to obtain its
envelope function which is then sampled by the
A-D converter at a 4 kHz rate. As a reference fre-
quency the time code carrier frequency is filtered,
limited and multiplied by f in a phase locked loop.
The synthesized frequency is then used as the sampling
pulse for the A-D converter.

After a shot is detected and processed, the
computer, through a D-A converter to an oscilloscope,
repetitively outputs the digitized shot together with
two pulses. One pulse showing the shock wave onset
time and the other the bubble pulse maximum. This
display is used by the operator to evaluate the
quality of the determination. The option also
exists to output the scope display on the chart
recorder at a scale factor of 0.125 ms/1mm for
further study. A typical display at 1/5 normal
time scale is shown in Figure (2).
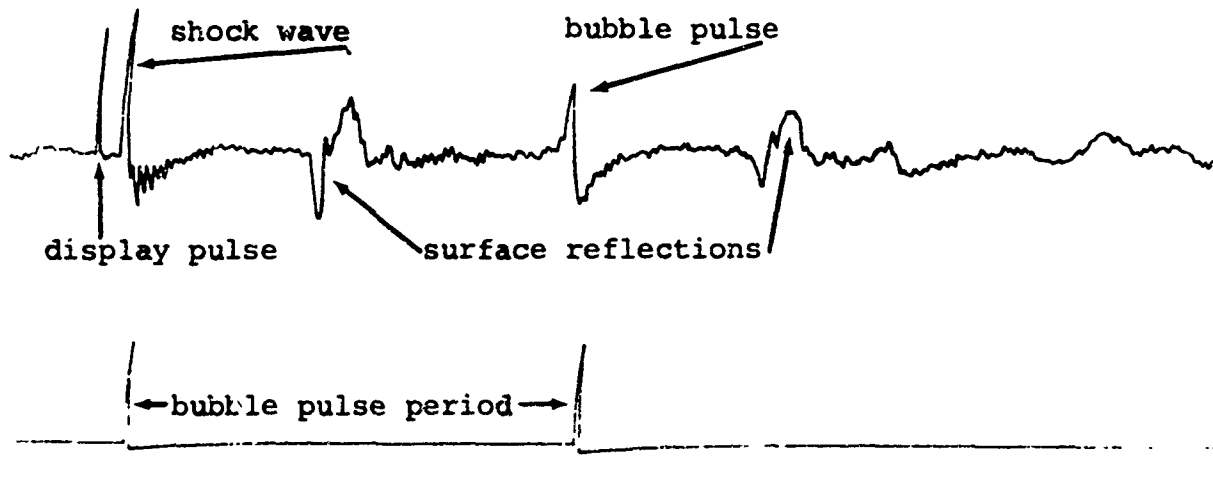
Figure (2). Typical SUS signal display at
1/5 normal time scale.

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Using the measured bubble pulse period and
assuming an explosive charge of 1.8 lbs of TNT, the
detonation depth is derived from the following formula:

$$T = \frac{4.36 \ W^{1/3}}{(Z + 33)^{5/6}}$$

where T = bubble pulse period

W = charge weight

Z = detonation depth

The curve for T as a function of Z was fitted with
a polynominal, this was used to derive the detona-
tion depth from the bubble pulse period.

Computer Operation

The design of the system minimizes the recurrent
menial tasks that the operator must perform so that
he can concentrate on evaluating each bubble pulse
determination. The initialization of the system
requires the manual entry via the TTY of expected
time of signal. A block diagram of the computer pro-
cessing routines are shown in Figure (3). The
system then monitors the time code until the decoded

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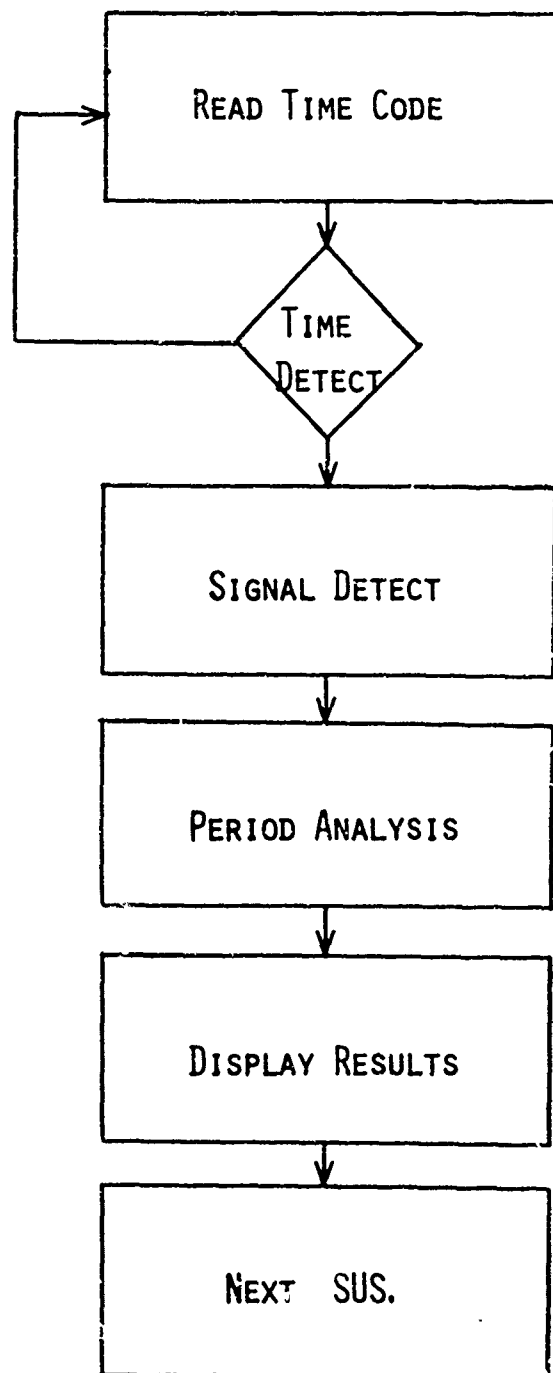
FIGURE (3). GENERALIZED BLOCK DIAGRAM OF
COMPUTER PROCESSING FOR EACH SUS SIGNAL.

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time is equal to the entered time minus 10 seconds

at which time it begins monitoring the SUS signal.

The shock wave is determined by level detection,

when this happens the following block of digitized

data is stored. The peak of the bubble pulse is

determined by recurrent looks at the stored data

with successively lower comparative levels. When

the peak level has been found it is compared with

the expected time frame of occurrence; if the

detection is outside the time frame an alarm is

sounded to alert the operator of a possible mis-

determination. The determination is displayed

following this.

Processing Results - USNS Silas Bent

A total of 1309 detonation pressure time

curves were processed. This represents 94% of

the charges dropped. The remaining 6% includes

54 Duds, as well as unprocessable and unrecorded

detonations. Table 1 summarizes this information.

Figures (4) and (5) show acumulative dis-

tributions as a function of bubble pulse period

and shot depth. The most likely bubble pulse

period is somewhat longer than the expected nominal
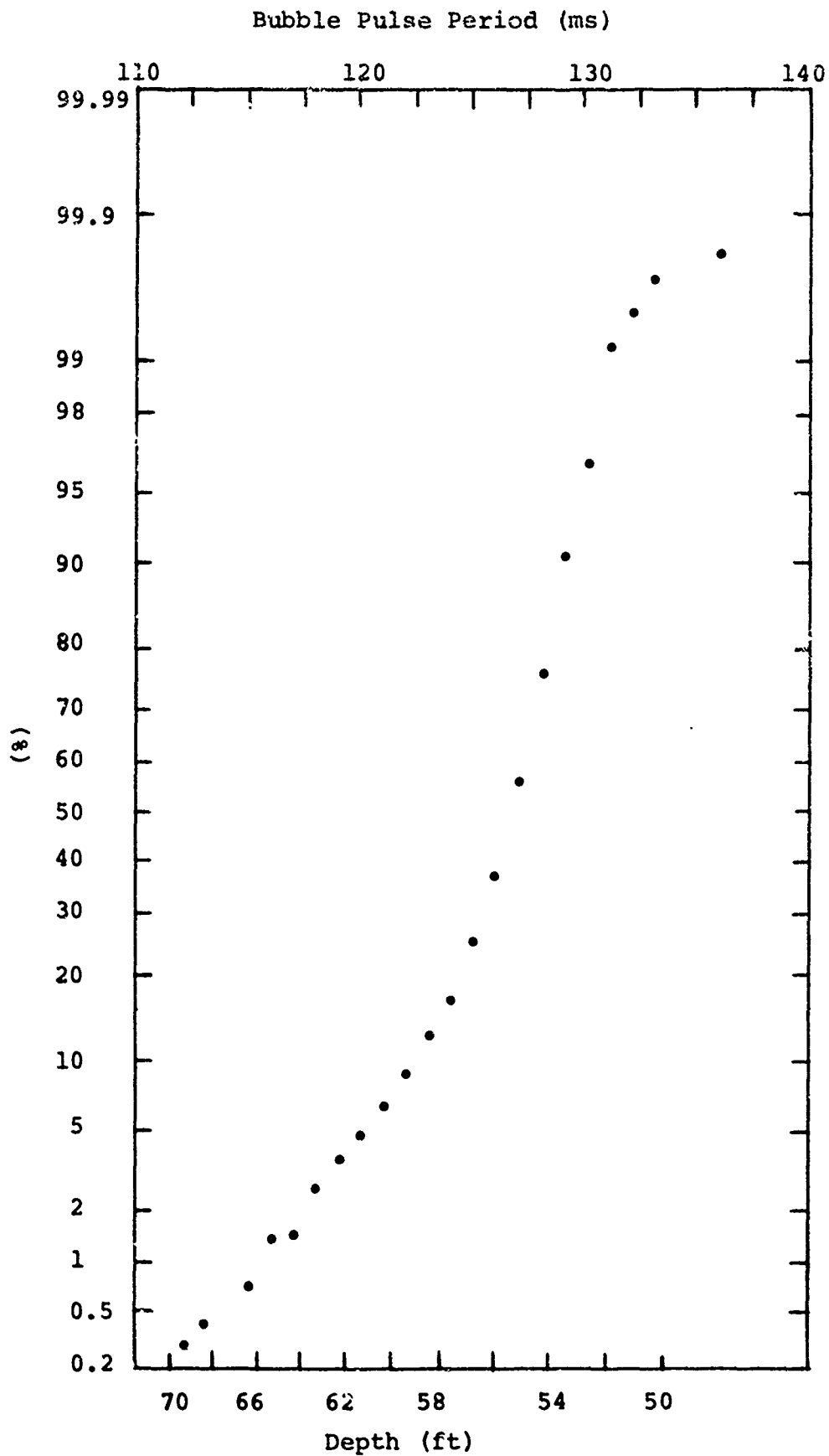
Figure (4). Cumulative distribution of bubble pulse period and derived shot depth from the MK 61 (60 feet) SUS charges dropped by the USNS Silas Bent.
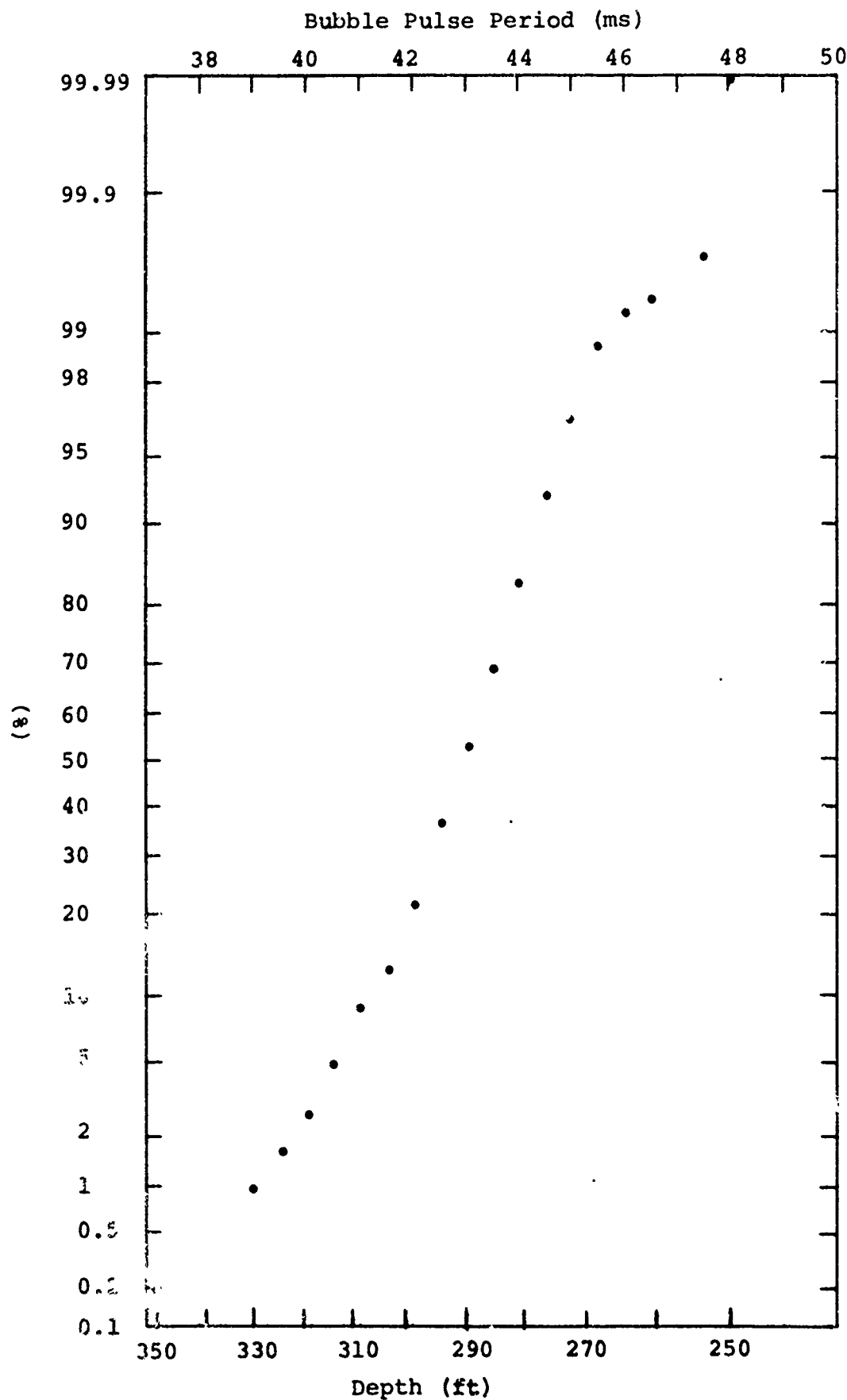
Figure (5).Cumulative distribution of bubble
pulse period and derived shot depth from the
MK 82 (300 feet) SUS charges dropped by the
USNS Silas Bent.

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value; 128 vs 121 ms for the MK 61 and 43.5 vs 42 for the MK 82.

This longer than nominal bubble pulse period in itself does not detract from the quality assurance concept, but may be the result of two things. The charges are detonating shallow, or the exploding charges vaporize some of the aluminum of the containers thus increasing the bubble pulse energy. In either event the shot to shot variation in source level is primarily controlled by the bubble pulse period regardless of its cause, assuming detonation of the whole charge. In evaluating the data, since the bubble pulse period is a function of both the effective charge and detonation depth, it seems desirable to improve the data quality by eliminating questionable shots. Since longer than average bubble pulse periods can generally be attributed to shallow detonations and short bubble pulse periods to partial detonation or deep detonation it seems desirable to recommend the deletion of the bottom and top 5% of the distribution shown in Figures (4) and (5). This limits the range of bubble pulse periods from 119 to 130 ms for the 60 foot MK 61s and from 41 to 45 ms for the 300 foot MK 82s. This corresponds to a little over one half the specified depth range

tolerance for each of these SUS; such a tight dis-
tribution also indicates total detonation. Correc-
tions in spectral level for the observed depth varia-
tions are shown in Table 3 of Chapter 3.

A shot list has been furnished to ARL which
has become part of their computerized data bank.
It is proposed that for each processed shot, that
its shot number be compared with that in the data
bank to determine if the bubble pulse period falls
within the acceptable 90% range, if it does a suitable
correction can be found from the computerized table
of spectral corrections for the several shot depths
and added to the source level. If the shot is out-
side the 90% range it is recommended that the shot
not be processed.

Shot numbers 1933 to 1962 were not recorded and
hence could not be evaluated. It is recommended
that the processing of these shots be optional.
The missing time code or the last ten reels of tape
does not seem to materially affect the data quality,
except that the quality cannot be proven. Subjective
evaluation shows the data to have the same magnitude
and the previous good tape speed control lends con-
fidence to the reliability of the measurements obtained
from these tapes.

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Processing Results - USNS Bartlett

A total of 118 detonation pressure time curves were processed. This represents about 61% of the data. The large amount of unprocessed data results from two causes besides duds; (1) tape speed errors in excess of 50%, and (2) shots not recorded while a malfunctioning tape recorder was replaced. Table 2 summarizes the above information.

Figures (6) and (7) show cumulative distributions as a function of bubble pulse period and shot depth.

If the top and bottom 5% of the distribution are rejected one finds that the longer bubble pulse periods are nearly identical to those observed from the Bent data but that the bounds of the shorter periods are about 15% less than for the Bent data. In another test only the data from the Visicorder and tape 5 were used; the bubble pulse periods for the MK 82's were offset from the Bent data by several milliseconds although they came from the same lot. Such discrepancies indicate that no positive quality assurance can be derived from the data at hand. It is recommended that array processing of the shots dropped from the Bartlett be optional since no reliable estimate of the quality of the SUS sources are available.

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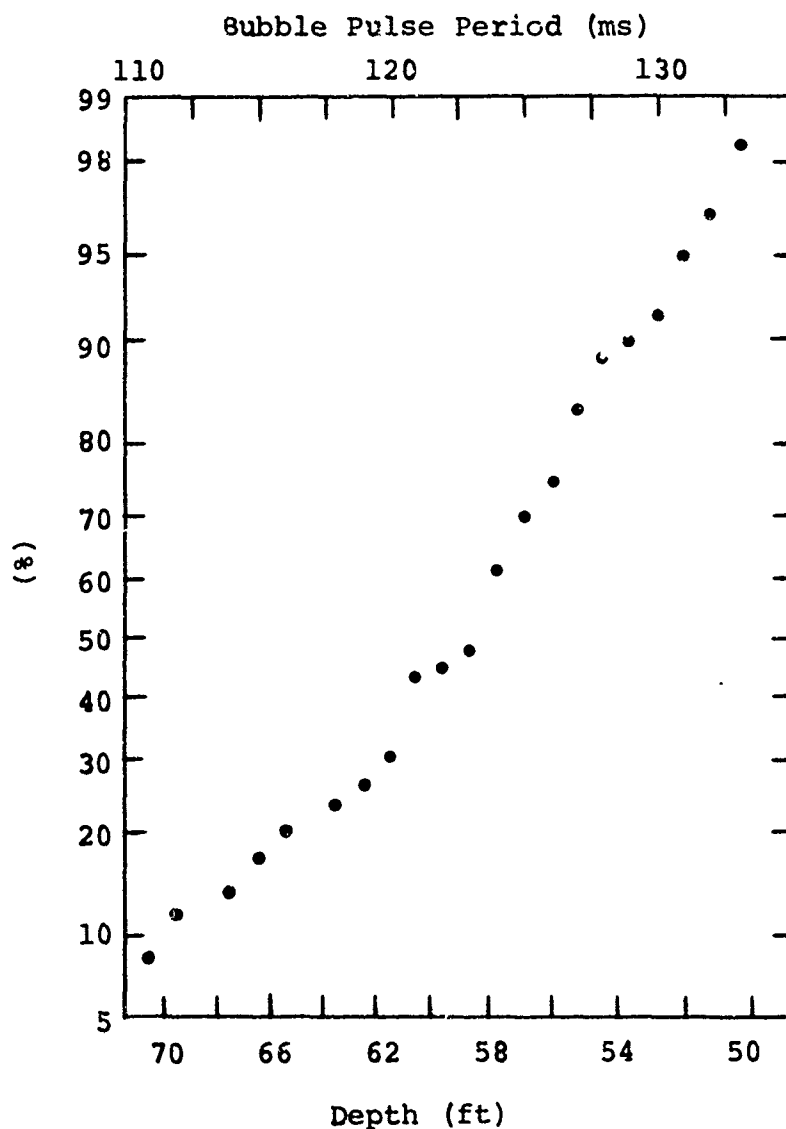
Figure (6). Cumulative distribution of
bubble pulse period and derived shot
depth from the MK 61 (60 feet) SUS charges
dropped by the USNS Bartlett.

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Bubble Pulse Period (ms)
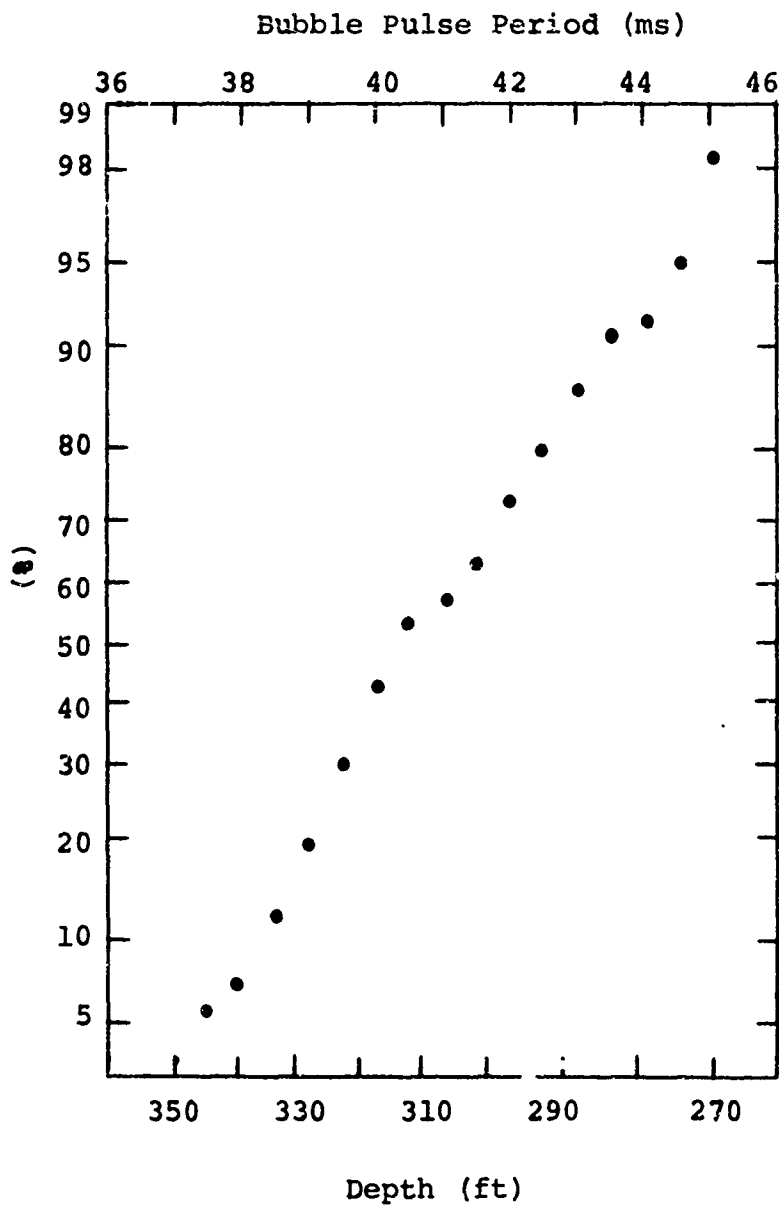
Figure (7).Cumulative distribution of
bubble pulse period and derived shot
depth for the MK 82 (300 feet) SUS
charges dropped by the USNS Bartlett.

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Quality Control

Errors in the determination of the bubble pulse period have two origins, (1) the basic data, and (2) the measurement of the bubble pulse period. The bubble pulse period is defined as the time bounded by the onset of the shock wave from the explosion and the bubble pulse maximum. Tape speed variations on record and playback will affect the measured time. In the present processing scheme the time code carrier was used for controlling the sampling rate and hence the relative change in tape speed variations are removed. The only inaccuracy in this methodology is the deviation of the time code carrier from 1 kHz, which is small since it is derived from a crystal oscillator with a stability of 1 part in 10^{-5} per day.

The measurement of the bubble pulse period by automated processing will cause an error which is dependent on how closely each signal matches the anticipated signal for which the computer program was written. A check was made throughout the processing from sample shots, comparing the computer determination to a scientist's determination. The differences between the two

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different bubble pulse determinations are shown
in Figure (8).

The operator monitored each shot for
accuracy of bubble pulse period determination.
Two rules were used to reject a computer deter-
mination.

1. The shock wave onset time was picked
more than 3/8 ms ahead of the apparent onset
time.

2. The bubble pulse maximum was not
picked.

If one of the above conditions existed or
the time frame alarm sounded the operator would
make a paper record of the shot for post evalua-
tion. If the computer determination was in error,
corrections would be made to the bubble pulse
period data manually. For the USNS Silas Bent
data 15 corrections needed to be made for a total
of 1309 processed shots. For the USNS Bartlett
data 19 corrections were made for 98 automatically
processed shots. This difference in error rate
shows that better data quality can greatly improve
the error rate in automatic data processing systems.
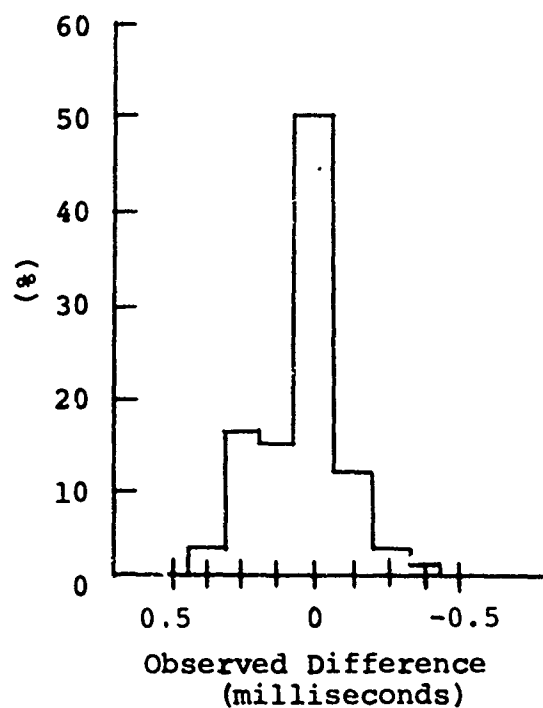
Figure (8). Distribution of differences
between computer determined bubble pulse
periods and manually determined periods
from a sample of 150 determinations.

The Bartlett data shows that a considerable number of the detonations have unreasonably short bubble pulse periods. A probable cause for these short bubble pulse periods cannot be pinpointed, the MK 82s are from the same lot as those used by the Bent. It is doubtful that shipboard handling can make the difference, and the processing was the same as the Bent. Figure (9) shows the calibrated error voltage from the phase lock loop for the 1 kHz time code carrier at the end of tape 3. Although the speed stability is poor in this example, there is no evidence of losing lock as is demonstrated in Figure (10) for comparison.

Since the causes for the Bartlett data not agreeing with the Bent's, and because of the poor quality of the recordings, the quality of the bomb shot data from the Bartlett cannot be assured.
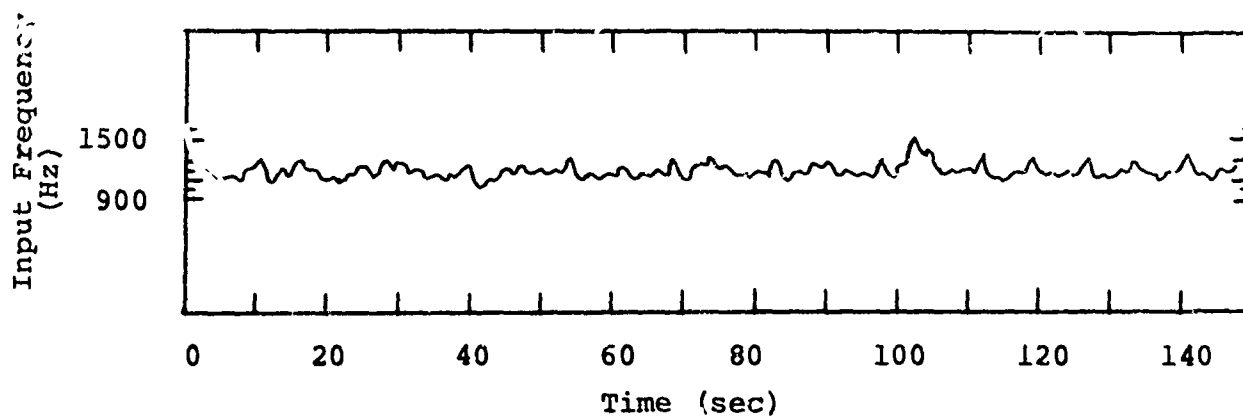
Figure (9). Phase lock loop error voltage as a function of frequency near che end of tape 3.
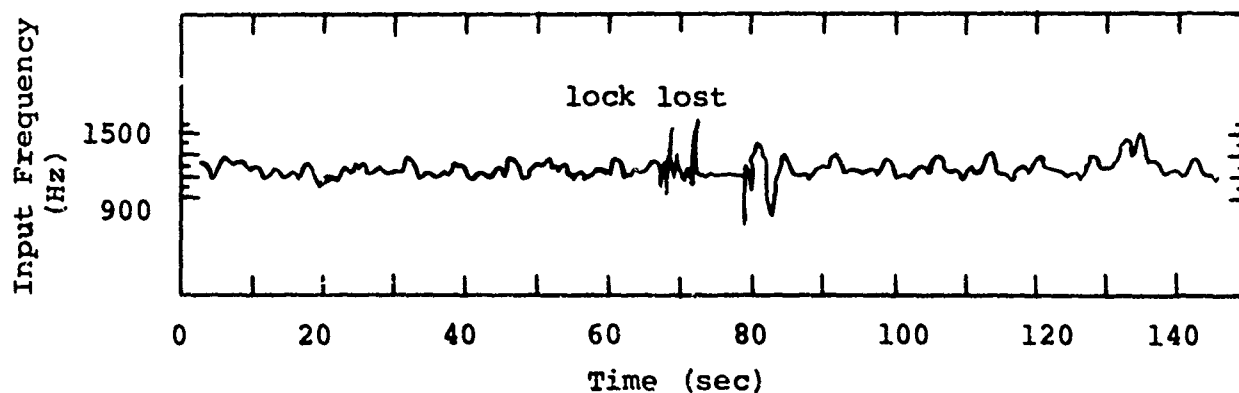
Figure (10). Example of a phase lock loop losing lock causing loss of synchronization.

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CHAPTER 2
ABSOLUTE SOURCE LEVELS

Because of the extensive use of SUS bombs as explosive sources one would expect that their levels would be well known. Unfortunately this is not the case; equivalent source levels are known to only a few decibels, particularly at the lower frequencies and for the shallower detonation depths. This is due to a number of reasons, discussed below.

Range Dependent Parameter

Simplified theory, Ref. (1), indicates that the early part of the shock wave can be represented by a decaying exponential, $p = Pe^{-t/\theta}$. The shock wave amplitude (P) decreases with range to the 1.13 power; the time constant (θ) increases with range to the 0.22 power. Fourier analysis of this time function indicates that at very low frequency, $2\pi f \ll 1/\theta$, the energy contained in the shock wave decreases with range to the 1.82 power. At high frequency, $2\pi f \gg 1/\theta$, the energy in the shock wave decreases with range to the 2.26 power.

The concept of an equivalent acoustic source level is based on the assumption that the signals can be treated by considering acoustic spreading

loss and absorption. For an acoustic source in
free space the energy decreases with range squared.
Thus, at the shorter ranges the shock wave energy
does not follow acoustic propagation laws. Since
the shock wave amplitude decreases with range, it
is assumed that a point is reached at which the
amplitude is sufficiently low so that signal behaves
as an acoustic signal for longer ranges. This
introduces the concept of a transition range between
shock wave and acoustic propagation laws. The
equivalent acoustic source level of the SUS bomb
should be determined at the transition range, and
extrapolated back to one yard based on acoustic
laws. The difficulty is that the transition occurs
gradually, and is poorly understood. The concept
of a specific transition range is a computational
convenience. It has become fairly standard to
compute the SUS bomb level at 100 yards, and to
extrapolate back to one yard to obtain the equi-
valent source level. For a 1.8 lb SUS bomb, the
shock wave amplitude at 100 yards is approximately
40 psi, hardly low enough for propagation to
greater range to follow acoustic laws. As a
result, equivalent levels will be too low at the
lower frequencies, and too high at the high fre-
quencies. There is a continuous transfer of

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energy from high to low frequencies as long as the signal follows shock wave laws. The differences resulting from the choice of computational range are by no means insignificant. For example, if the equivalent source levels were computed at 1,000 yards corresponding to a shock wave amplitude of about 4 psi, the low frequency level for the shock wave would be 1.8 db higher, and at the high frequencies it would be 2.6 db lower.

In addition to the shock wave, the bubble pulses contribute significant energy at the low frequencies, and little energy at the high frequencies. Since the bubble pulse propagation is believed to follow acoustic laws, the above cited difference of 1.8 db will be reduced considerably at the low frequencies, but the 2.6 db difference at the high frequencies would still be present.

In summary, if a rigorous procedure for computing the energy in the signal generated by SUS bombs were available, it is likely that the choice of 100 yards for the computation would result in equivalent source levels which tend to be too low at the low frequencies and too high at the high frequencies.

Experimental Measurements

Approximate analytic functions which describe the major features of the signals generated by SUS bombs have been derived, Ref. (1). These analytic functions can be used to compute the spectra. Secondary effects which are not accounted for, or are poorly approximated by the formulae, result in equivalent acoustic source level errors of a few decibels. An attempt to take these into account using a graphical method based on experimental data is described in Ref. (2).

Mathematical computations are used rather than direct experimental measurement of spectral levels because of the special difficulties encountered in direct measurements, particularly for shallow detonations. The primary problem is that the surface reflection is received prior to decay of the bubble pulse train. For example, for a detonation depth of 60 feet, and a monitoring gage below the charge, the surface reflection arrives 24 milliseconds after the direct receipt of the signal. By contrast, the first bubble pulse arrives approximately 120 milliseconds after the shock wave. The reflected portion of the signal must

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be removed, or deconvolved, before the true source
spectrum can be determined. This is difficult to
achieve, because of two reasons. First, since the
duration of the shock wave and bubble pulses is
very short, milliseconds or less, deviations from
a flat ocean surface must be accounted for. Secondly,
because the pressures are quite high, and a 180°
phase shift occurs at the surface, the reflected
signal will produce cavitation. The result is a
surface cut-off effect, truncating the shock wave
and bubble pulses. As a result, the reflected signal
cannot be precisely defined, and therefore, cannot be
properly removed from the total signal. Neverthe-
less, attempts at such measurements have been made
and are included in the tables presented later in
this report.

It is apparent from the previous discussion of
the range dependence of the shock wave, that com-
parisons between experimental and computed spectra
must be undertaken for identical ranges. In past
work, different investigations have used different
ranges, but a tendancy to reduce levels to 100 yards
has emerged in recent years. As noted, this may be

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too short since the shock wave amplitude for a 1.8
lb charge is still quite high at 100 yards. As a
practical matter, increasing the range introduces
additional difficulties. As the horizontal separa-
tion of charge and receiver is increased, the surface
reflection arrives at an earlier time, and refraction
effects may have to be considered. Placing the gage
at a depth of 3,000 feet requires that the experi-
ment be conducted in deep water with all the pro-
blems of control which that entails.

A major problem, frequently overlooked, is the
nature of the charge itself. Theoretical analysis
assumes a spherical charge, and does not take the
charge casing into account. By contrast, SUS bombs
are built with a rigid aluminum casing. It is known
that the inclusion of aluminum dust in an explosive
mixture alters the generated signal. Specifically,
the bubble pulse period is increased, and probably
its energy content is modified. The energy required
to burst the casing may also modify the total radiated
energy.

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A second major problem with SUS bombs results from the manner in which the bombs are manufactured as determined from Ref. (3) and conversations with Mr. Greenlaw of NAVAIR. The nominal TNT yield is 1.8 lbs, but, additionally there is a nominal 1.1 oz of Tetryl in the booster, and 0.2 oz of Tetryl in the cup. The TNT is poured in three stages: (1) an initial pour to a specified volume, (2) a second pour to top off after the froth settles out from the first pour, (3) a third pour if after cooling the weight of the first two pours is less than 1.7 lbs. Because of this sequence in manufacture, and the weight tolerance, the TNT is layered, and the total yield, in our judgement, is between 1.7 and 1.9 lbs. The quality assurance procedure is based on measuring the first bubble pulse, so that

whether variations are due to a variation in yield or detonation depth, the spectral correction will be properly accounted for. Errors in shot depth and absolute level will occur and are tabulated below.

Depth Error

  60 foot depth, ±2 feet

  300 foot depth, ±7 feet

Level Error

  low frequency level, ±.3 db

  high frequency level, ±.2 db

Absolute Source Levels

Source levels from several different data sources are listed in Tables (3) and (4) for the 1/3 octave bands specified for processing CHURCH ANCHOR data. The differences between the various columns is discussed below.

1. Column (1) from Ref. (2), is a semi-empirical computation based on experimentally recorded pressure time histories for different depths and theoretical considerations. Any surface reflections occurring in the pressure time history of the detonation are removed by hand; the resultant hand drawn curve is digitized and an FFT was used to compute the spectral levels. It differs from the computations of columns (4) to (6) in two significant ways. The negative going portion of the signal is faithfully represented, whereas for columns (4) to (6) the negative going portion is approximated by a constant value rectangular impulse, extending from the shock wave to the last bubble pulse considered in the computation, balancing the positive going impulse. Secondly, the shock wave time constant (θ) used in columns

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(5) and (6) is given by Weston. It is known that
(θ) is correct only out to about 2θ after which the
shock wave decays more slowly. Weston, Ref. (1),
notes that an alternative computation of the time
constant from the measured impulse yields a value
some 40% higher and may give a better representation
of the low frequencies. Gaspin and Shuler, Ref. (2),
go further, and indicate that the impulse for a 60
foot charge is 80% higher than Weston's value, based
on the work of Slifko, Ref. (4). Unfortunately, this
is based on an extrapolation, since Slifko worked with
detonation depths of 500 feet or greater. The effect
of these and other analytic differences is to increase
the source level at low frequency and to decrease the
level at high frequency for the Gaspin and Shuler
computations.

2. Column (2) gives source levels provided by
NAVOCEANO in connection with a prior USI program,
Ref. (5). The data originated at NUSC from experi-
mental measurements. The measurement range and the
extent to which the surface reflection was removed
is unknown to us. Column (3) gives a second set
of source levels based on unpublished NUSC measure-
ments.

3. Column (4) derived from Ref. (2) is stated
to be a recalculation of levels based on the impulse

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formula given by Weston, Ref. (1). The exact manner
of computation, and whether the parametric values
given by Weston were used, or those of Slifkc, is
not known to us.

4. Column (5) is computed using a modified
form of Weston's analysis derived by Weinstein.
It is based on a fourier analysis of the pressure
time history using the analytic forms given by
Weston, and including only the first bubble pulse.

5. Column (6) repeats the computation of
column (5) but includes two bubble pulses. A
comparison of columns (5) and (6) indicates that
the inclusion of the second bubble introduces
corrections of only a few tenths of a decibel,
except for the 25 Hz band in Table (4).

6. Column (7) was provided to us by Earl
Hayes of WHOI, and is based on experimental measure-
ments performed by J. Busch of BTL. The measurements
were made with MILS hydrophones at a range of about
one n.m. The received signals were FFT processed.
The effect of surface reflections was removed by
analysis of the spectra.

An examination of these data sets indicates
that, in general, the data provided by Busch (BTL)
is a lower limit, while the computations by Gaspin
& Shuler are an upper limit. Only a few data points
lie outside these limits for the remaining data sets.
Until the discrepancies between the data sets is
resolved the selection of the best source level is
reduced to a subjective judgement.

We recommend that whichever set of data is
selected, it should be used for processing all
LRAPP data, and that all propagation loss reports
document the source levels used.

TABLE 3

Source Level in 1/3 Octave Bands
1/8 lbs at 60 foot detonation depth
db re: 1 erg/cm^2/Hs at 100 yards

Band Levels
several data sources

Center Frequency (Hz)	1	2	3	4	5	6	7
25	20.0	-	12.3	17.9	16.0	16.3	12.4
35	-	21.6	-	-	-	-	-
50	14.9	-	9.4	15.9	14.7	15.1	13.0
65	-	15.5	-	-	-	-	-
100	13.7	12.4	7.7	16.2	14.1	14.4	8.0
160	10.3	-	6.3	12.7	12.1	12.2	5.6
200	-	9.4	-	-	-	-	-
250	8.6	-	5.1	11.0	10.1	10.2	5.7
360	-	5.9	-	-	-	-	-

Data Sources

1. Gaspin & Shuler, Ref. (2)

2. NAVOCEANO & NUSC, reported in Ref. (5)

3. Unpublished NUSC Data

4. Weston, Ref. (1), as recomputed by Gaspin & Shuler, Ref. (2)

5. Weinstein, fourier transform of Weston parameters, one bubble pulse

6. Weinstein, fourier transform of Weston parameters, two bubble pulse

7. J. Busch, BTL

TABLE 4

Source Level in 1/3 Octave Bands
1.8 lbs at 300 foot detonation depth
db re: 1 erg/cm^2/Hz at 100 yards

	Band Levels several data sources						
Center Frequency (Hz)	1	2	3	4	5	6	7
25	20.7	–	18.7	–	16.1	18.1	15.8
50	15.7	–	13.2	–	15.1	15.3	11.8
100	13.3	–	10.2	–	13.3	13.8	8.7
160	11.5	–	8.5	–	12.1	12.1	6.7
250	9.1	–	6.9	–	10.1	10.2	5.0

Data Sources

1. Gaspin & Shuler, Ref. (2)

3. Unpublished NUSC Data

5. Weinstein, fourier transform of Weston parameters, one bubble pulse

6. Weinstein, fourier transform of Weston parameters, two bubble pulse

7. J. Busch, BTL

CHAPTER 3
FLUCTUATIONS IN SOURCE LEVELS

The preceding chapter was concerned with pre-
dicting the source levels for nominal yields of
1.8 lbs detonated at depths of 60 and 300 feet.
In this chapter we will be concerned with the
changes in source level which occur as a result of
small deviations from these nominal values. Fluctua-
tions in the received signal level can be ascribed
to the following causes.

1. Changes in the bubble pulse periods due
to either a variation of shot depth or yield will
alter the shape of the source spectrum. The varia-
tion in source level in fixed bands is determined
by the relationship of peaks and nulls in the
spectrum relative to the measurement band. By
measurement of the first bubble pulse period primary
effects are identified.

2. A variation in yield will also change the
total available energy. This was treated in the
preceding chapter in which narrow error bands were
established.

3. When the variation in bubble pulse period is due to a variation in yield, the computed detonation depth, based on the formula given below for a nominal yield of 1.8 lbs, will introduce a small error. This was also treated in the preceding chapter.

$$T = \frac{4.36(W^{1/3})}{(Z + 33)^{5/6}}$$

where: T = first bubble pulse period

W = yield (pounds of TNT)

Z = detonation depth (feet)

4. Variations in shot depth will also cause a variation in received signal level resulting from changes in the propagation loss, entirely apart from any changes which may occur in source levels. This effect will not be treated in this report.

The remainder of this chapter is devoted to an examination of the variation in source level due to item (1) above.

The goal of quality assurance for the SUS bomb data is to ensure that source level fluctuations do not exceed ±1 db. This is achieved in the following fashion.

1. Reject all SUS bomb shots which fall in the lower and upper 5% of the shot depth distribution so that the range of depths which need to be considered is small.

2. Apply spectral corrections in 1/2 db steps for the acceptable SUS bombs.

Although there are large differences between the spectral levels derived from the different computational procedures, the shape of the spectra are similar. Since the absolute levels are not rigorously correct, it follows that the detailed spectral shape will not be correctly given by any of the computational procedures. To establish corrected spectral levels we have compared the corrections derived from the computational models used for columns (1) and (6) of Tables (3) and (4). The corrections to be applied for the range of accepted shot depths is given in Table (5).

Details of Comparison

Ref. (2) tabulates spectral corrections for a nominal shot depth of 60 feet, but not for 300 feet. To compute the correction at 300 feet the plotted spectrum was digitized and integrated after applying a spectral shift factor determined from the ratio of the bubble pulse period at 300 feet to that for other depths. To check the accuracy of this first order approximation the method was also applied for selected frequencies and detonation depths about a nominal depth of 60. A comparison of the corrections given in Ref. (2), the corrections computed from the curves published in Ref. (2), and the corrections computed with the analytic formula, are shown in Tables (6) and (7). The corrections listed in Table (5) agree with these results to within ±0.5 db.

TABLE 5

Spectral Correction for square 1/3
octave bands. Corrections in db to
be added to the nominal levels for
1.8 lbs detonated at 60 or 300 feet

Detonation Depth	Center Frequency				
	25	50	100	160	250
54	-0.5	+1.0	0	0	0
56	-0.5	+1.0	0	0	0
58	0	+0.5	0	0	0
60	0	0	0	0	0
280	0	-1.0	0	-1.0	+1.0
290	0	-0.5	0	-0.5	+0.5
300	0	0	0	0	0
310	0	0	0	0	+0.5
320	0	0	0	0	+1.0

TABLE 6

Comparison of Computed Spectral
Corrections, square 1/3 octave bands,
1.8 lbs, nominal depth 60 feet

Depth	25 Hz			50 Hz			100 Hz			160 Hz			250 Hz		
	1a	1b	5	1a	1b	5	1a	1b	5	1a	1b	5	1a	1b	5
50	-0.5	-0.9	-0.8	+2.2	+1.7	+0.5	-0.2	-	+0.1	+0.7	-	+0.3	+0.4	-	0
52	-	-	-0.9	-	-	+1.0	-	-	-0.2	-	-	+0.4	-	-	-0.2
54	-	-	-1.0	-	-	+1.2	-	-	-0.2	-	-	0	-	-	0
55	0	-0.2	-	+1.1	+1.2	-	-0.3	-	-	+0.4	-	-	+0.2	-	-
56	-	-	-0.8	-	-	+1.1	-	-	-0.2	-	-	-	+0.3	-	0
58	-	-	-0.4	-	-	+0.6	-	-	-0.1	-	-	+0.5	-	-	-0.2
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: (1a) From Tables in Ref. (2)

(1b) Computed from spectra published in Ref. (2)

(5) Analytic formulation derived from Ref. (1)

TABLE 7

Comparison of Computed Spectral
Corrections, square 1/3 octave
bands 1.8 lbs, nominal depth 300 feet

Depth	25 Hz		50 Hz		100 Hz		160 Hz		250 Hz	
	1b	5	1b	5	1b	5	1b	5	1b	5
270	-	-0.3	-	-1.2	-	-0.3	-	+0.2	-	+0.2
280	+0.5	-0.1	-1.2	-0.8	-0.1	-0.1	-1.3	-.6	+.6	+1.0
290	-	0	-	-0.3	-	-0.1	-	-.6	-	+0.6
300	0	0	0	0	0	0	0	0	-	0
310	-	-0.1	-	0	-	+0.2	-	+0.6	-	+0.6
320	-0.4	-0.2	+0.3	-0.1	+0.1	+0.2	-0.1	+0.7	+0.9	+1.1
330	0	-0.4	-	-0.4	-	+0.2	-	0	-	+0.6

Notes: (1b) Computed from spectra published in Ref. (2)

(5) Analytic formulation derived from Ref. (1)

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WHOI73-59	Tollios, C. D.	THE ACODAC DATA PROCESSING SYSTEM	Woods Hole Oceanographic Institution	730901	AD0773114; ND	U
Unavailable	Russell, J. J.	DOCUMENTATION FOR COMPUTER PROGRAM SUMMARY: A COMPUTER PROGRAM TO SUMMARIZE SOUND SPEED PROFILE DATA	Naval Undersea Center	731001	AD0918907	U
MC001Vol2	Unavailable	CHURCH ANCHOR DATA ANALYSIS PLAN VOL 2 (U)	Maury Center for Ocean Science	731001	ND	U
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Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: CONTINUOUS CURRENT PROFILES	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740101	AD0775333	U
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